TOWARDS SOFTWARE INTEGRATION IN THE CONSTRUCTION INDUSTRY – ERP AND ICIS CASE STUDY

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ABSTRACT

Construction industry is traditional, resistant to change and has lack of investment in new technologies. These statements are frequent and are often used as an excuse for inefficiencies, time and cost overruns. Through time, many methodologies and software were tempted to solve particular problems. Like Construction Information Classification Systems – CICS during their first years of existence, the development of applications for the construction sector was focused in specific issues. Nowadays, there are several classification systems with the purpose of classifying all the industry. The same trend is being reflected in computer applications, either by being broader and/or interoperable with each other. This challenging path involves many processes and elements through the different stages. This paper approaches the problems that arise from the implementation of Information Technologies - IT on enterprises related with the construction industry. The construction stage was the main aspect in study. Integration situation are explored. Standard Work Breakdown Structure for Construction Works, detailing the work description is assumed as the central element, assuming a key point for these integrations. The potential results of the integration methodology are explored.

Keywords: work breakdown structure (WBS), integration, construction stage, communication, improving processes

1. INTRODUCTION

The Enterprise Resource Planning - ERP's are known as systems that aim the integration of all departments of a company. They extent it into a single computer system that suites all their particular needs. This Information Technology - IT has been widely adopted and performed a revolution on the work mode of several institutions. The wideness of ERP functionalities transform it on a complex project. Many studies and know-how have been collected from implementation processes. Many of them are not exclusive of this type of systems and can be used on others.

Construction Information Systems - CIS, in some aspects have comparable ambitions with the ERP. Yet, their essential object and scope is different. The central aspect of a CIS is the construction project through its life cycle.

The departments referred for the ERP are constituted by people that perform a team. In this aspect the essence is the same. However, when it comes to the use of CIS on a project, the teams do not belong to the same enterprise. They usually come from different companies, have likewise distinct roles and get together to undertake a specific project. This situation is very important and distinctive. The temporary nature of these teams have influence on behavior and accomplishment. Some studies point routine has a step for the success (Saumyendu, 2010). Nevertheless, when addressing to construction, this condition is not valid or in minimum, is less usable.

Facing this, it is possible to say that ERP and some CIS might have similar complexity and wideness, despite the potential extra difficulties when facing construction projects.

This paper addresses to a specific situation found during the construction stage. The implementation of two systems led to the identification of new problems. The success of the information technologies – IT, namely those that are wide in range and usability, is related with their ability to communicate and integrate with others (Saumyendu, 2010). The underestimation of crossing points during implementations processes can add significant complexities and problems.

2. PROBLEM DESCRIPTION

The process of adopting new methodologies or Information Technologies – IT is iterative. There is always the need to carefully define all the requirements and implementation stages, in order to validate/perform corrections on the developments. This task is never easy, especially if the ambition is to manage all the processes involved on construction projects from the stages before the design to the end of construction. To become things more difficult, the use of several software on the processes, increases the demands in terms of knowledge and communication exchange requirements.

To express the difficulty of this task, one specific situation is identified.

This occurred during a program of implementation of Information Technologies – IT on a public entity related with construction and management of public buildings. This institution usually assumes the role of work owner and has developed significant efforts to improve its practices.

Due to the adoption of IT that will be further detailed, it was detected the need to establish communication between two software.

In this situation the software are an ERP system that supports the company activities and the operation of the different departments and an ICIS - Integrated Construction Information System to manage the construction projects. The absence of communication was leading to an increasing workload, namely the need to enter the same data in both applications and outputs as inputs to one another. Facing this, improvements could be made. A study was performed, in order to define and implement communication procedures. The initiative aimed the reduction of the workload, the minimization of errors, assuring at the same time greater consistency, more reliable results, process speed up and a "cleaner" methodology.

To better understanding, it is pointed in general terms, some of the sector specificities and problems. Also, a brief resume about the implemented systems, emphasizing some aspects of the ERP's and their importance in what concerns the adoption of wide technologies – difficulties and main benefits. It is highlighted the uniqueness and the know-how acquired by the entity during the process. The efforts, the touch points and the methodologies are described in detail, enhancing the gains expected. Other touch points for further studies are also referred.

3. ENTERPRISE RESOURCE PLANNING

3.1 Brief State-of-Art about ERP

ERP systems origins date back to early 70's (Radovilsky 2004). Their first application was on manufacturing and production planning systems (Fitzgerald 1992). As in every initiatives, there were developments stages, with the inclusion of new and wider functionalities. These intended to fulfill and achieve to the growing needs. The evolutionary process was necessarily constant and continuous, leading on different moments to different levels, designations and functionalities. Without detailing too much, the initial scope oriented for storage and allocation of production materials and ability to manage and plan inventories was changed to the calculation of materials requirements including information needs for management and decision support about other production resources (Castro 2009). From MRP – Materials Requirement Planning, to ERP, passing by MRP II, many changes occurred.

ERP designation comes from the production-oriented systems integrated with purchasing, financials, human resources and other applications to enhance the management of all business operations across the enterprise. The scope continued to expand during the 90's, including new back-office functionalities as order management, financial management, warehousing, distribution, quality control, asset management and human resources (Shi 2003). In recent years, the evolution of the internet - that will be further highlighted, and growing needs related with electronic commerce and supply-chain systems led to a new impulse on developments (Hare 1999).

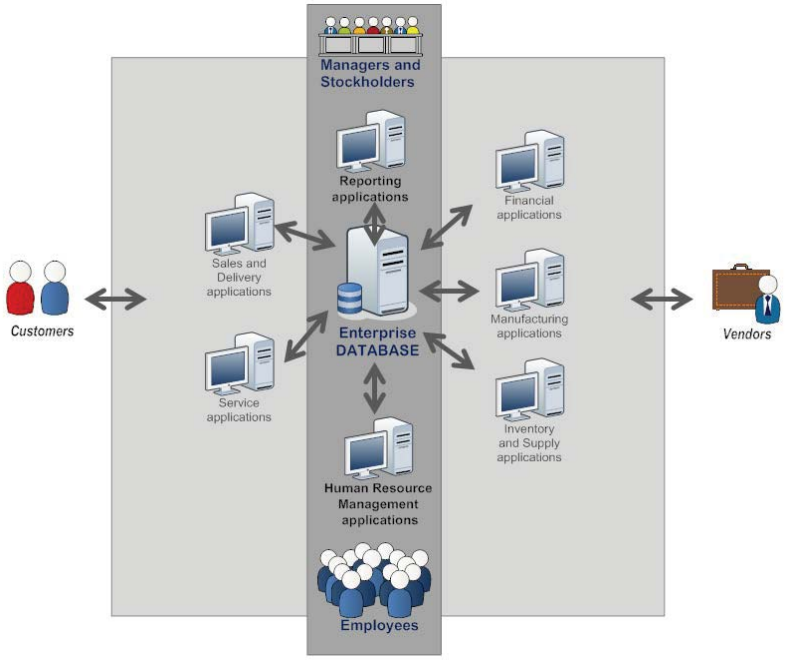

Figure 1: Typical ERP structure of operation, based on Davenport, 1998

One possible definition for ERP is the following: "*Enterprise Resource Planning systems are configurable information systems packages that integrate information and information-based processes within and across functional areas in an organization*" (Kumar 2000). In simple terms, ERP is a computer program that provides a general working platform for the enterprise departments including their specific management functions among other common or specific functionalities (Laudon 2004). It also provides the storage and management of all relevant information. Allows the use of a single database speeding and easing up the communication and information share.

It is important to understand that the system has a modular structure, providing an horizontal data integration across the organization. The packages can be configured and adapted to meet the specific needs (Esteves 1999). In addition, these modules can be configured to interact with other organizational systems. Hence, nowadays in many industrial areas the ERP are not assumed as a software. Their importance on the processes and on the enterprise daily actions, transformed them on the backbone Information Technology - IT of the corporate infrastructure (Bechler 1997).

The Internet had a significant impact on all technologies and the ERP was no exception. The system became accessible everywhere and at all time. This improvement opened way for the direct intervention of customers and vendors, among others. Upgraded the satisfaction, increased the sales opportunities and distribution channels (Teixeira 2005).

3.2 ERP implementation - Introduction

There are several studies about the implementation of ERP on the enterprises. They attempt to identify the reasons that lead to the adoption, balance the gains obtained and the difficulties. These are, in fact, essential aspects in which the ERP were pioneers. Many lessons learned about ERP implementation are

useful for other systems. Different reasons lead to the decision of implementing an ERP. This process, requires a conscious analysis of the impacts and changes on the organization, the involvement of all actors specially the top ones, and those with decision-making capacity. The process is not simple, as it involves many people from different departments and with very different visions about the outputs. Some performance losses can occur during the process. In what concerns technological infrastructure it usually leads to the replacement of the equipment. This, may also be seen as an improvement towards the modernization of the support hardware.

In order to start implementing an ERP there should be an awareness of the changes. They cannot be faced with resistance. Generally, other situations such as shortcoming on processes, lack of productivity, product quality and essentially overspendings, contribute to heighten the readiness for change. Some studies point six common reasons for ERP adoption (Ross and Vitale 1998).

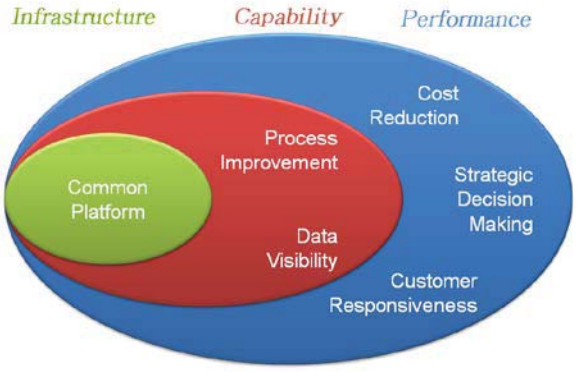

Figure 2: Motivations for ERP systems adoption

The most common gains expected with the implementation of an ERP are: Information integration, Information quality improvement, Improvement on the decision-making process, Suppression of redundant activities, Improvement on productivity, Valuation of the company, Improvement on business results and Improvements on customer service.

In order to achieve these gains and performance, there are some key aspects to fulfill. As referred, it is fundamental to obtain commitment from all the intervenient as they need to identify, understand and overcome the resistances and the challenges (Gambôa and Caputo 2004). One other aspect is the persuasive effort and focus on the process as the results will not all be achieved at the first time. A commitment with the results must be made in order to achieve them (Deloitte Consulting 1998). Yet, it is possible that in this evolutional path of the processes new problems might arise. These situations can impair the acceptance and operation of the system, by which, it should be assessed as much and as far as possible in order to be solved in compatible time.

3.3 ERP implementation on construction industry

In some aspects, construction industry enterprises are not different from others. As an example, the ERP module for human resources it might be similar to those implemented on other sectors. However, regarding to the production process, this industry presents some singularities that may contribute to higher difficulties. One of the evidenced aspects is the restructuration of processes through ERP, giving rise to well-defined business rules and allowing stricter controls (Miltello 1999). The business on construction, may not follow always the same rules and therefore, rigid definition may become undesirable and an obstacle to achievement. Other hypothesis is a sectorial implementation, not covering the construction process. On these situations, manual work for inputs needs to be performed (with consequent problems involved), as this activity is directly linked with several ERP modules.

There are conclusions from studies about ERP implementation on construction industries. Many of them are similar to those referred to other industries. It is noteworthy that the improvement on the

processes can be slower. In what regards the construction process or ERP Engineering Module, it is evidenced that there are many difficulties due to the transient nature of the process, different time periods, variability of work types, construction works and resources (Shi 2003). This affects the ability of the ERP to produce unitary costs, budget estimative, planning, and construction follow up (Corrêa 2011).

Many researchers have the opinion that specific systems must be performed for the construction industry. One of the distinctive aspects is that a Construction Enterprise Resource Planning system, in order to answer to the needs of a construction process will necessarily need to be focused on the project. Other hypothesis could pass through the integration of different and specific systems on some processes related with construction.

4. INTEGRATED CONSTRUCTION INFORMATION SYSTEMS

Integrated Construction Information Systems - ICIS are specifically oriented for the industry. Its origins date back to the middle of the XXth century (Sousa 2008a). ICIS inherit many years of developments performed on Construction Information Classification Systems - CICS. These mechanisms appeared to supersede some growing difficulties that were frequently arising in some processes. So, more or less since the decade of sixty, with the development of the "CSI Format Specification for Building" to nowadays and to systems like "Omniclass" and "Uniclass" (Crawford 1997), a long way has gone. In the beginning, the CICS were focused on achieving to specific issues. With it, they reached to parts of the construction. There were many initiatives with different scopes. They were usually focused on buildings or on civil engineering works. Some intended to be transversal in terms of work types, being more focused on measurement rules. Others were focused on materials. Each one, was more or less used by the industry. Different achievements and solutions were obtained. (Kang 2000) Yet, the traditional essence of the construction, its relative lethargy and fragmented structure, contributed for some failures to update. Most of these initial mechanisms were constituted by work breakdown structures that were published as a reference to follow rather than a rule. The rise of Information Technologies allowed new possibilities and new systems shown up, integrating previous works and guidelines. A study identified the landscape of developments, by areas of research, functionalities and outputs of a group of initiatives (Boddy 2007).
The complexity and the relative regional characteristics of each country construction, have not contributed to the definition of a single system.

Considering that, it is not possible to have just one system with all the rules and specificities of each country construction. The establish of some general principles was essential. ISO performed the work producing the ISO 12006-2 standard, published on 2001 (ISO 2001).

In resume, these systems are liable of the construction industry specificities. They include elements that reflect traditional aspects of the type of construction performed (mainly on the Work Breakdown Structures for Construction Works and Materials - WBS), as well as national regulations. They include also, many aspects that are used in other industries and processes.
Nowadays, the higher demands expected from a ICIS are the following:

- Wideness in terms of work types, construction stages, construction information, actors, functionalities, outputs.
- It must be project oriented. The project must be the central aspect of the ICIS;
- Other characteristics that are not so specific of the ICIS, like open, expandable, collaborative, accessible, internet based and updatable.

ProNIC project, that is "Protocolo para a Normalização da Informação na Construção, in english Protocol for the Standardization of the Construction Technical Information (Sousa 2008a) started its developments focused on the establishment of work breakdown structures for construction works in two distinct areas - buildings and roads (Sousa 2011). The definition of standard works with specific classification and coding, parameterized work descriptions, standard measurement rules, technical specifications for the works and definition of materials with their specifications, was the main objective. This development took more than one year. There were identified potential outputs for this information as well as functionalities for different actors. To answer these requirements, all the information was inserted

on a software with management capacity and that could perform suitable interface with the users. New demands brought by the Public Contracts Code fostered new functionalities (Sousa 2008b). In generic terms, the definition of new functionalities and essentially, the establishment of a collaborative environment and a governance model for all actors management on the different stages was determinant. The system with all this characteristics, became substantial on construction projects management from design to the end of the works, enabling the participation of many actors, from work owners to contractors, including designers and supervision.

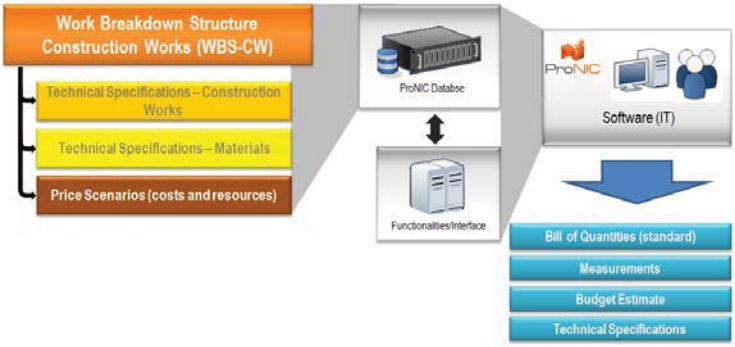

Figure 3: ProNIC main information elements and outputs

The system was adopted by a public work owner to improve its management processes on construction projects. New developments took place, foreseeing new functionalities and small adjustments. The characteristics of this ICIS are presented to better understand the outputs and the information exchanges. Mainly, because the study is based on a public entity that adopted it for project management.

5. ASSUMPTIONS AND METHODOLOGY FOR INTEGRATION

On any process it is necessary to understand the problem, study possible solutions and implement or develop the best means to supersede and achieve to improvements. However, describing the processes seems much more easy than producing them and put into operation. The situation that supports the need of the described study and development initiative, is the overload induced by the implementation of information technologies - IT. The process is related with the construction stage and the need to define communication procedures. The actor involved and more affected by the absence of them is the work owner. The improvement of other processes led, at the end, to a duplication of effort, due to absence of communication. The use of additional human resources to perform exclusively these kind of tasks is unnecessary, as they are redundant, very unproductive and reveal a high margin for error. Facing this, the identification of situations where communication procedures between systems, could solve problems, minimize errors and could perform significant improvements on the global process, was the main object of study.

In essence, the results identified two types of processes.

As mentioned, the focus was mainly to the construction stage. Situations on other stages were also superficially observed. Some remarks are presented further. The identified processes involve the production and processing of payments to the contractor and the establishment, management and definition of new works, in accordance with the legal framework. These works, after acceptance, are assumed as additional. They lead to additional contracts and to additional payments processed through additional monthly measurement reports.

The first type of process – designated by *"Pr1"*, traditionally has its beginning on the monthly measurement report that is delivered by the contractor to the work owner. After verification/adjustments and acceptance, the document is sent to the financial department of the work owner to perform the payment. In order to control the project, the amounts are inserted on specific tools to perform the invoice. This process occurs to the main contract and to any other additional contracts that might happen during

the project. The described procedures are mainly performed by hand. Nowadays, ERP systems incorporate and perform all controls and production of invoices. Nevertheless, to perform them, there is always the need to insert the information provided by the contractor or supervision teams. These are often monthly measurement reports, signed and on non-editable format or spreadsheets with the values. Both prevent the direct upload (format or absence of templates). As the documents are sent by other actor, they are performed according to the company specific methodologies and/or software. Because of the differences, the information is placed by hand.

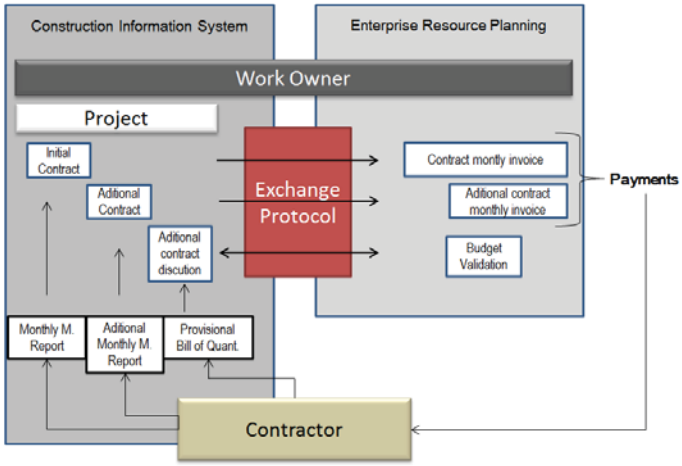

Figure 4: Processes during construction stage, were communication between ERP and ICIS was found essential

The second process is rather complex as it depends largely on the methods and procedures adopted by the work owner – designated as *"Pr2"*. The legal framework settles the timings and controls, but does not provide details about the mechanisms. There is a certain level of freedom to choose the methodology that is best in each specific case. In order to perform additional works, the contractor addresses to the work owner and to the supervision information regarding the need for these works. A summary bill of quantities with the work descriptions will be prepared and discussed. The establishment of unitary prices for the works, quantities and global value is fundamental for budget control and to approval. If the conditions are verified and if it is possible to perform the works, the bill of quantities and values are discussed with the contractor and the process is closed. The actors involved are the work owner, supervision, contractor and design team. They all participate on the definition of the works, quantities needed and unitary prices. These works lead to a new contract "additional", that will be invoiced through additional monthly measurement reports. This process has maximum time determined by the law. The traditional form, involved discussion and management on work site, the use of spreadsheets and email for information exchange. The process, with more or less need to discussion, would end with the signature of the additional contract. As referred, some of the processes are new and were brought by the regulation, namely the Public Contract Code – CCP (Sousa 2008b). Facing these demands and the workflow defined by the work owner, the process implies much more steps, controls and exchanges. In what concerns the present case study, the owner has two systems that perform many of the iterations defined. Yet, in order to achieve to an additional contract there are some exchanges that, as referred are performed by hand. The *"Pr2"* workflow and the information exchanges, is resumed on Figure 5.

The communication between the ERP and the ICIS on the referred processes is established using a web service. Both systems operate independently. At present, is what is happening. Yet, the clear definition of timings or conditions for information exchange allows the information to pass from one system to other automatically. It was possible to find that these moments were related with clear defined workflow steps. Also, the role of the systems.

They are clearly defined for specific issues. So, they use the same base information and their functionalities are pointed for different results. These results or outputs, are the required inputs on the

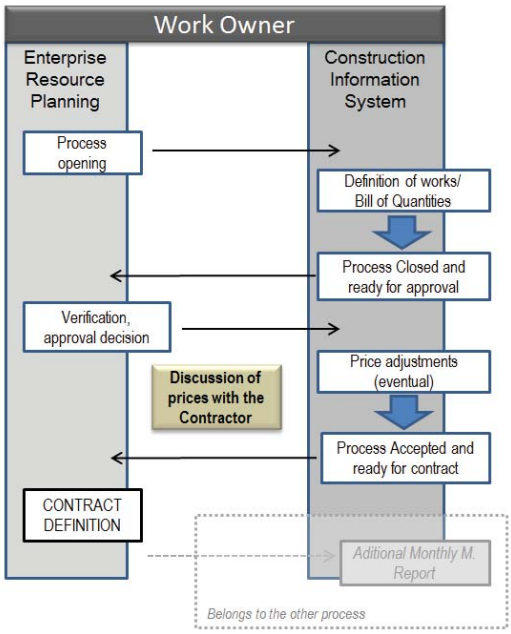

Figure 5: Scheme of information exchange between ERP and ICIS during additional contract management *"Pr2"*

other system. Facing this, it was possible to outline a new workflow or procedure. This defines the not simultaneous use of the systems. When the information is transferred from one place to other, the system that sends information becomes blocked until receiving new inputs. In each step, it was identified the information needs, namely its type, origin and final destination. In terms of type and formats, the transactions will involve numeric values (mainly prices), text (example: name or title of the contract or of the work to be done) or files (mostly digital signed .pdf's).

As referred, the two processes are quite different in terms of transactions.

Pr1, is much simpler and it is expected only the transaction of information from the ICIS to the ERP. This information comprises files with final documents and values for invoice processing.

Pr2 involves mutual exchanges. This is much more demanding in terms of exchanges itself, but also in terms of mutual delivery/receiving confirmation, error report and system blocking.

In what regards to document storage, both system have the capacity to keep the documents. After signing the contract there will be the need to measure and pay these works. This situation will fit on *Pr1*.

At, present time all the requirements were identified and the communication exchange protocols are set. As there is some freedom on the procedure, some modifications were performed, causing some delays on development. The systems are operating independent and the procedure is being evaluated through the simulation of the information exchange using manual process. The work is being performed by hand. Nevertheless it is not possible to consider it traditional, as standardized templates are being used, namely on measurement reports. This constitutes an evolution as the output as always the same aspect. It is a small step on evolution. Basically, the work consists of download and upload information on specific moments on the systems, through the use of import mechanisms and templates. Besides testing the workflow, this also has intention of training the actors for the future procedures and to improve their knowledge and capacities to evaluate the "process during processing". It is expected that the connection (web service tool) would be ready for testing this year.

6. MAIN ACHIEVEMENTS AND CONCLUSIONS

There is an ongoing discussion about the borders and boundaries of ERP. It seems very difficult and maybe, not desirable to ERP systems to integrate all the project information. As referred, its base and essential object is the enterprise, in what the project is just a small part. In what regards ICIS, they have as

essential object the project and its integration, covering all stakeholders in all stages. It seems therefore reasonable to explore the integration of different systems, using common languages, communication protocols and web services, to suit specific needs of each actor. This allows distinct and complementary dynamics with respect to each specific area.

The situation described is a real case, where a specific work owner adopted an ERP on its enterprise processes, namely those related with finance and a ICIS with the described characteristics to perform and manage its construction projects. There were benefits from the adoption of both systems on the processes of their specific fields. Yet, in what regards transversal processes the absence of communication was performing a step back on the intended optimization and on the desired objectives.

The development of an environment, allowing easier communication between systems and desirably their interoperability became necessary. This situation is not always easy or peaceful, as it involves mutual knowledge needs from part to part about the systems back office. Nevertheless, it will be essential in a short term to promote it.

At this moment, the establishment of a communication platform through web service it is the best, easiest and fastest solution, to solve most of the problems.

From the studies and work performed it is possible to evidence main advantages. However, before listing them it is worth note the efforts required to standardize processes and to establish common rules for mutual understanding and trade conduct. Overcoming these difficulties, integration would enable:

- Work evolution management and payment processing - it will be unnecessary the download and upload of final documents from one system to another. The insertion by hand of the same data won't also be needed. The monthly measurement reports and the additional monthly measurement reports are produced, validated and closed on the ICIS. Then, the information will then be sent to the ERP for bill processing.
- Creation of additional works - there are several steps/information exchanges involving the two systems. There are higher demands in terms of data transfer. The use of templates speeds up the process. Yet, it will be possible to improve the time savings through the elimination of redundant data entry. Exchange becomes fully automatic, needing however activation by the authorized users. At the same time, it is assured higher consistency and flexibility of the information and errors reduction.

In summary, the integration will potentially lead to "cleaner" procedures, with less working hours, minimizing the occurrence of errors from manual data insertion and providing better control of the work evolution.

As mentioned, the work aimed specifically the construction stage and it was geared for the identification of very objective issues. Nevertheless, the chosen technology is able to support other processes on other stages, if the exchange protocol is settled.

An outline reflection towards further studies, leads to other processes involving the same systems and different actors. From this it is possible to identify communication needs between:

- ICIS and ERP from a product manufacturer – The incorporation of materials database is essential to upgrade the design process in terms of knowledge about materials, their characteristics and main applications. The definition of standard codes and designations for materials is the way to cross information from manufacturers to designers;
- ICIS and Work Owner ERP during competition – to better define the contract and to integrate the information from the different bids;
- ICIS and Contractor ERP during construction stage – to cross the materials and works performed with the contracts. It may be also applicable to sub-contracting management.

These are just some examples from others possible. There is a long way towards the complete integration on the construction, in wich the acquired know-how and the investments performed have a very important role. Other investigation lines are complementary like the ones studying on BIM. In this issue, CIS can and should constitute the base structure of BIM. Relations between ICIS and ERP can and should be performed between BIM and ERP (Santos 2009). Being the construction sector transient in terms of nature -different projects usually imply different teams and companies, scale is very relevant. Many changes are occurring quite fast. This speed might be not well seen by the sector. The adoption of these

systems by a significant number of companies participating with different roles will necessarily improve the performance of all in particular, including the systems and the sector behavior in general.

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